دراسة امتصاص الإشعاع

(دراسة معامل الامتصاص الخطي والكتلي لأشعة جاما)

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ملخص الدراسة :

تعتبر هذه الدراسة العلمية المقدمة مفيدة لمبادئ الإشعاع وقياسه وتفاعله مع المواد، من خلال طريقة امتصاص وانتثار (الفوتونات) أشعة جاما فيكون الهدف منها هو توضيح كيفية توهين (امتصاص) الإشعاع في المادة وتعيين معامل الامتصاص الخطي للمادة، وأيضا تعيين معامل الامتصاص الكتلي للمادة.

قبل أن نبدأ في التجربة يجب أن نتعرف علي خصائص أشعة جاما وتفاعلاتها مع المادة، وتخفيف شدتها أثناء التفاعل مع أنواع من المواد المختلفة وسمكها كالتي تم استخدامها في هذه الدراسة كالألومونيوم والنحاس والقصدير والرصاص والتي تم وضعها أمام مصدر جاما (AM-241) في هذه التجربة ، حتي يساعدنا في شغلنا.

فكرة التجربة هي انبعاث الفوتونات من المصدر والتي تضرب الكاشف NAI(TL) detector الذي يبلغ قطره 2 بوصة,ومن خصائص هذا الكاشف هي الشفافية والتوفر بحجم كبير وإخراج الضوء الكبير المتناسب مع أشعة جاما. ما سيحدث هو أن أشعة جاما التي تتفاعل مع أداة الوميض أو الكاشف scintillator detector تنتج نبضة كهربائية بواسطة أنبوب مضعف ضوئي PMT والذي يتكون PMT من كاثود ضوئي (الكترود) و10 أو أكثر من الدينود (الديناميات) والتي تضاعف عدد الالكترونات التي تصطدم بكل داينود, وسلسلة من المقاومات الموجودة عادة في تجميع قاعدة الأنبوب المكونات في تحيز الأنود والديناميات.فيكون الكاشف موصل بالكابلات بجهاز ذو الجهد العالي وأيضا متصل ب MCA الذي تم وضعه داخل جهاز الكومبيوتر مع نضام التشغيل ويندوز لتسجيل القراءات والتي منها سوف نقوم بحساب معامل الامتصاص الخطي والكتلي للمادة علي سبيل المثال الالومنيوم عند سمك0.42 فيكون معامل الامتصاص الخطي هو0.297 ومعامل الكتلي هو0.110 .

في الختام أو نهاية التجربة حصلنا علي أفكار جيدة حول طبيعة المصادر المشعة وما هو سلوك إشعاعها ـ أيضا ـ وكيفية قياس طاقة المصدر، وقياس شدة الفوتونات الممتصة من خلال قياس توهين المواد المختلفة التي تم استخدامها.

Absorption of radiation (study of linear and mass absorption coefficient of gamma rays).

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Abstract

Multichannel analyzer (MCA) provides an array of counting channels, or scalars, and systematically stores incoming pulses in these channels according to some prescribed criterion. The criterion defines a mode of operation. MCA can scan a whole energy range and record the number of pulses they count in each of the channels. A full width at half maximum (FWHM) is an expression of the extent of a function, given by the difference between the two extreme values of the independent variable at which the dependent variable is equal to half of its maximum value. Gamma rays are photons (quanta of light) and have no electric charge and no rest mass. Therefore, the interaction of gamma rays with matter is weak. There are 3 mechanisms that are important from the point of view of radiation protection such as (i) photoelectric effect (ii) Compton scattering (iii) pair production. This work will focus to photoelectric effect.

The idea of the experiment is when the photons emitted from the source and strike the detector,The PMT consists of a photocathode, a focusing electrode, and 10 or more dynodes that multiply the number of electrons striking at each dynode. A chain of resistors typically located in a plug-in tube base assembly biases the anode and dynodes. Complete assemblies including the scintillator and PMT are available. The properties of a scintillation

material required to produce a good detector are transparency, availability in large size, and large light output proportional to gamma-ray energy. Sodium iodide [NaI(Tl)] crystals are commonly used. The high Z of iodine in NaI(Tl) crystals result in high efficiency for gamma-ray detection. Resolution for a 2inch diameter by 2 inch length crystal. The light decay time constant for a NaI(Tl) crystal is about 0.23 μs. Typical charge-sensitive preamplifiers translate this into an output voltage pulse with a rise-time of about 0.5 μs. Fast coincidence measurements cannot achieve the very short resolving times that are possible for plastic scintillators, especially at low gamma-ray energies.

So a good signal will appeared from the MCA represented by peaks we take the bigger one to get the results .

And before we start the details of our experiment we'd like to going into some properties of gamma ray and its interactions with matter according to the probability of its interactions and the attenuation of its intensity during the interaction with different types and thicknesses of materials, as we used the (AM-241) source of gamma.

1. Objective

There are two main objectives for this work as noted below:

- To familiarize with the operation and function of a Multichannel Analyzer (MCA)
- To study the absorption of gamma rays by Al, Cu, Sn and Pb.

2. introduction

The gamma ray is as electromagnetic waves have no charges emitted from the nucleuses with mono energetic value of energy so the gamma photons could be consider as a thumb for the isotope. Gamma rays are emitted when a nucleus has been formed (after some decay process) in an excited state. Which shows the nuclear energy levels in ‘daughter’ nuclei produced in the sources we will use in this experiment. Notice how each gamma transition has its own probability I_γ of being emitted per disintegration.

The incident beam will be attenuated by the absorbed matter through it passes the material and every material has specific attenuation factor. Two types of attenuations we will go in with, the linear attenuation coefficient **μ** which depends on the energy of the incident photon and the **Z** of the material and the mass attenuation factor **μm**.

The attenuation coefficient which has given in this form:

$$I = I_o e^{-\mu X}$$

Where **I** is the incident beam**, I**◦ is the initial beam without interaction with the material, **μ** is the linear attenuation coefficient, X is the thickness of the material.

The mass attenuation coefficient is the **μ** divided by the density of the material **ρ**.

Theoretically, there should be an exponential decrease of the transmitted counts with thickness of absorber.

Multichannel analyzer (MCA) provides an array of counting channels, or scalars, and systematically stores incoming pulses in these channels according to some prescribed criterion. The criterion defines a mode of operation. MCA can scan a whole energy range and record the number of pulses they count in each of the channels. Nowadays, there is growing availability of plug in card that will convert personnel computer (PC) into MCA. The card must provide the components that are unique to MCA such as ADC. The normal PC memory, display, and hardware can be used directly. Control of the MCA functions is then provided in the form of software that is loaded into the PC memory. (Glenn F. Knoll, 1989)

A full width at half maximum (FWHM) is an expression of the extent of a function, f(x) given by the difference between the two extreme values (x_1 and x_2) of the independent variable at which the dependent variable is equal to half of its maximum value, (1/2) x $f_{max.}$ (see **Figure 1**). (U of T, 2006)

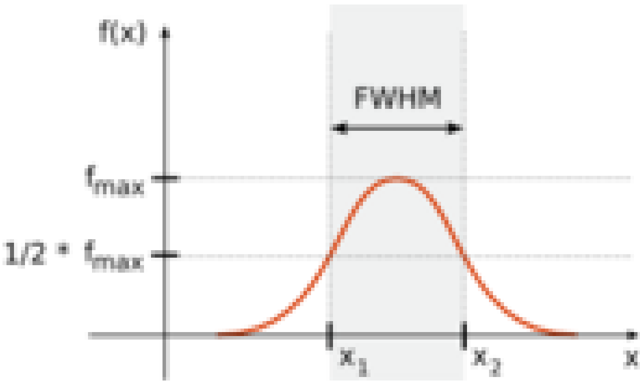

Figure 1: The description of full width half maximum (FWHM) (http://www.utoronto.ca/safety/RadTraining/Module3.html)

A radioactive source, Am-241 with half life of 433 years emits 0.0595 MeV or 59.5 keV of gamma rays which represented 35.3 % of photons emitted (W. H. Tait, 1980) is used in this experiment. Gamma rays are photons (quanta of light) and have no electric charge and no rest mass. Therefore, the interaction of gamma rays with matter is weak. There are 3 mechanisms that are important from the point of view of radiation protection such as (i) photoelectric effect (ii) Compton scattering (iii) pair production.

This work will focus to photoelectric effect. In photoelectric effect an electron is emitted from an atom (ionization process) with energy equal to the energy of the gamma ray. The electron then moves through matter and loses its energy as described for beta interactions. This is the predominant effect at low gamma energies. In Compton scattering the gamma ray interacts with an electron, causing an increase in the electron's energy. A new gamma ray with a smaller energy is then emitted. The new gamma ray can escape from the matter or can be absorbed through the photoelectric effect. The Compton effect is the predominant effect at intermediate gamma energies (U of T, 2006).

The linear attenuation coefficient is the probability that an X-ray or gamma-ray photon will interact with the material it is traversing per unit path length travelled. It is usually reported in units of cm^{-1}. The linear attenuation coefficient, μ depends on the photon energy and the chemical composition and physical density of the material. For mono energetic gamma rays, the fraction of incident gamma rays expected to penetrate through a thickness x without interacting with the material $e^{-\mu x}$.

The linear attenuation coefficient is equal to the mass attenuation coefficient (μ/ρ) multiplied by the density ρ. The advantage of expressing the linear attenuation coefficient in this way is that the mass attenuation coefficient is independent of density and can be computed from the mass attenuation coefficients of the constituent elements. For any material, the mass attenuation coefficient is a weighted sum of the Mass attenuation coefficients of the component elements, the weight being the fraction by weight of that element (Medcyclopaedia, 2006).

3. Apparatus

1. MCA system with software used winTMCA32
2. Gamma rays source Am-241

3. NaI (Tl) detector

Figure 2: Gamma ray source Am-241

Figure 3: NaI (Tl) Detector, Kinds of Tickness

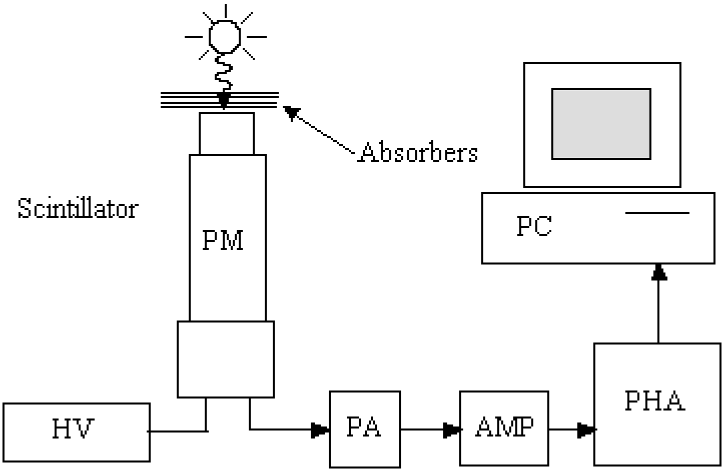

Figure 3 :Diagram of apparatus

Equipment: NaI scintillation detector, amplifier, pulse-height analyzer; gamma sources, sets of absorber plates.

(Medcyclopaedia (2018). Standard Edition. Available: http://en.wikipedia.org/wiki/Fwhm

4. Procedure

1. Total count under the 60 keV gamma peak of Am-241 for a period 300 seconds without any absorber material is obtained.
2. The FWHM of the gamma peak is calculated.
3. The total peak count for various absorbers between the source and the detector are obtained.
   A. Al (different thickness)
   B. Sn (different thickness)
   C. Cu and Pb (one thickness each)
4. The coefficient of absorption and the mass attenuation coefficient is calculated.
5. The variation of the attenuation coefficient with the atomic number Z is observed.

5. Results and discussion

Table1: The counts under the 60 keV gamma peak of Am-241 without absorber.

Peak	FWHM	FW (1/5) M	Net area	Net count rate (cps)
3763.42	441.81	689.49	703563 ± 4057	2341.88

I_o=net area/period =2341.88 cps (the intensity of the incident beam)

The linear absorption coefficient can be calculated using the following equation;

$I = I_o\, e^{-\mu x}$……………………………….(1)

Where

I = transmitted photon intensity

I_o = incident photon intensity

μ = linear absorption coefficient
x = thickness of the absorber
Equation (1) is rearrange to be
$\ln(I/I_o) = -\mu x$………………………(2)

Thickness (mm)	Peak	FWHM	FW (1/5) M	Net area	Net count rate (cps)
0.42	3767.94	416.74	653.36	619554±4587	2065.18
2.00	3764.31	416.38	622.28	509124±4663	1697.08
3.24	3764.33	429.57	637.77	502950±3993	1676.50
6.08	3759.01	437.61	667.43	441894±3200	1472.98

Equation (2) shows that $\ln(I/I_o)$ is directly proportional to x and μ is the gradient of that straight line. The negative sign indicated that as the thickness of the absorber increases the value $\ln(I/I_o)$ decrease.
The mass attenuation coefficient,
$\mu_m = \mu/\rho$……………………………(3)
Where ρ = density of the absorber
Percentage of standard deviation =
[(standard value - experimental value) / standard value] ×100
Aluminum Al:

Table 2: The total counts under the 60 keV gamma peak of Am 241 of Al

We can see the result on the table as below witch calculated by this equation : $\mu = -[\ln(I / I_o)] / x$
The attenuation of gamma ray by (Al) filter is shown in the Table 3:

Table 3: Attenuation of gamma ray by Al thickness

Thickness(x)	Ln(I /Io)	$\mu(cm^{-1})$	$\rho(\frac{g}{cm^3})$	$\frac{\mu}{\rho}(cm^2/g)$
0.42	0.125	0.297	2.702	0.110
2.00	0.322	0.161	2.702	0.05
3.24	0.334	0.103	2.702	0.038
6.08	0.46	0.07	2.702	0.028

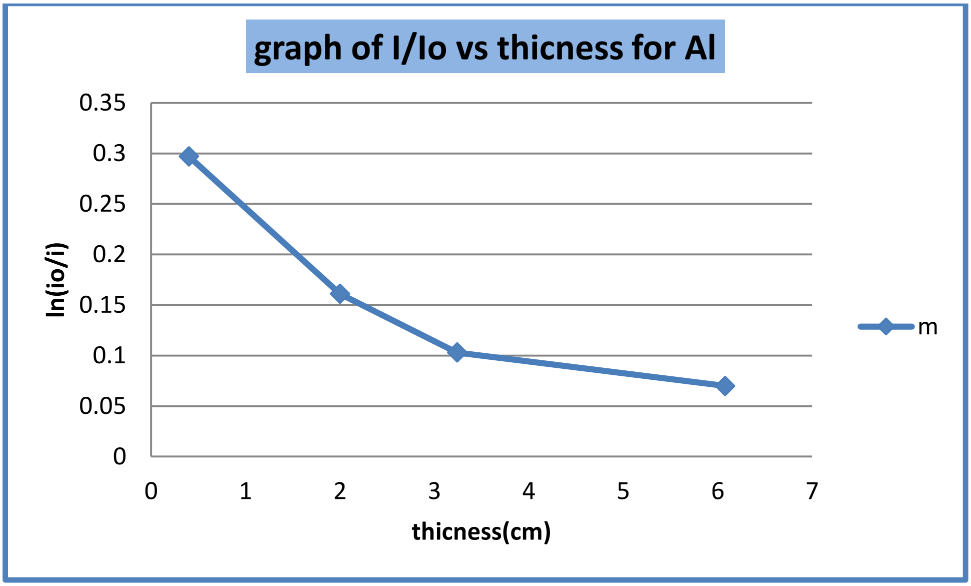

Figure 5: Plotted graph of Ln(I o/I) versus thickness of Al filter

Tin/Stannum, Sn:

Table3: peak a count for various absorbers between the source and the detector for sn

Thickness (mm)	Peak	FWHM	FW (1/5) M	Net area	Net count rate (cps)
0.11	3758.67	410.66	616.86	339134±3678	1130.45
0.21	3759.60	404.27	624.57	231891±2799	772.97
0.30	3757.72	423.61	661.34	176923±1682	589.74
0.42	3754.19	390.43	630.32	95600±1250	318.67

The attenuation of gamma ray by (sn) filter is shown in the Table4:

Table 4: Attenuation of gamma ray by Sn thickness

Thickness (mm)	Ln(Io/I)	Density(g/cm$^{3)}$	Linear attenuation coefficient (cm^{-1})	mass absorption coefficient (cm^2/g)
0.11	0.2728	7.31	6.6212	0.9057
0.21	1.108	7.31	5.276	0.721
0.30	1.379	7.31	4.596	0.628
0.42	1.994	7.31	4.748	0.649
average			21.241	0.726

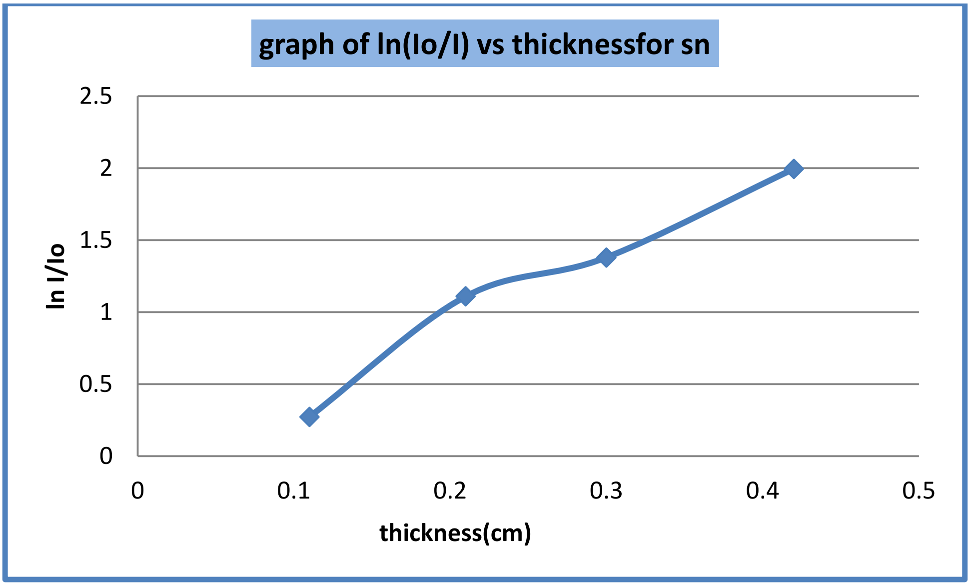

Figure 4: Plotted graph of CPS versus Sn filter thickness

The attenuation of gamma ray by copper (Cu) filter is shown in the Table 5 below:

Cooper (Cu):

Table 5: Attenuation of gamma ray by Cu thickness

Thickness (mm)	Peak	FWHM	FW (1/5) M	Net area	Net count rate (cps)
0.3	3765.71	402.03	608.51	422691±4240	1408.97

The attenuation of gamma ray by lead (pb) filter is shown in the Table 6 below:

Lead(pb):

Table 6: Attenuation of gamma ray by Pb filter

Thickness (mm)	Peak	FWHM	FW (1/5) M	Net area	Net count rate (cps)
0.32	3761.93	355.56	586.46	104290±2046	347.63

The attenuation of gamma ray by cooper(Cu) and lead (pb) filter is shown in the Table 7 below:

Table 7: Attenuation of gamma ray by (Cu) and(Pb) filter:

material	Thickness (cm)	Ln(Io/I)	Density (g/cm^{3})	$\mu(cm^{-1})$	$\frac{\mu}{\rho}(cm^2/g)$
Cu	0.3	0.508	8.98	1.693	0.188
Pb	0.32	1.907	11.83	5.96	0.503

The deviations of measured to calculated linear attenuation coefficient, μ are shown in the table above. The deviations are expected because material density and mass attenuation coefficient are calculated based on standard laboratory condition. Other factor such as thickness of filters used not really accurate due to poor storage and handling that will lead to oxidation and corrosion of that material. There are also other terms such as an absorption coefficient, or linear energy attenuation coefficient, μ_E

corresponding to the linear attenuation coefficient, μ. If E_a is energy absorbed from one photon, then $\mu_{mE} = E_a\mu_m/E$ or $\mu_E = E_a\mu/E$, where E is energy of individual particle or photon, μ_m is the mass attenuation coefficient and μ_{mE} is mass energy attenuation coefficient or the mass absorption coefficient. (W. H. Tait, 1980)

1. Conclusion

Multichannel analyzer (MCA) can be used to scan a whole energy range and record the number of pulses they count in each of the channels. The spectrum produced by MCA can be analyzed based on selected channels in the region of interest (ROI). A full width at half maximum (FWHM) is an expression of the extent of a function, given by the difference between the two extreme values of the independent variable (in this case channels) at which the dependent variable is equal to half of its maximum value. The absorption and scattering of gamma ray is due to photoelectric effect and Compton scattering in the medium of matter which interact with it. There are several factors affecting the measurement result in this experiment, the understanding of the MCA systems operation is important to get a good result, handling of the system should be under guidance of the expert, especially system with PC oriented. The deviations of the μ values are expected because material density and mass attenuation coefficient are calculated based on standard laboratory condition. Other factor such as thickness of filters used are not really accurate due to poor storage and handling that will lead to oxidation and corrosion of that material. The maintenance and calibration, and the proper handling of the system with written working instruction as a guideline are necessary in order to get a good result of this study.

Also in This study can be considered practicable and specific for the measurement of the radiation.

It's covered the important things for getting good and benefit information (the basely information's) of the principles of the radiation and its measuring and its interacting with materials, through the way of measuring the absorbing and the scattering of the photons. Since it is designed for using radioactive source emitting abeam of photons which these photons will interact with different materials.

The conclusion here is (these photons are being attenuated, either absorbed by these materials).

That's mean the incident photons removed from the beam either by scattering will case the attenuation to the intensity of the incident beam (Is) or by transmitted also case attenuation to incident beam (It), through the probabilities of each interaction.

The probability of interaction increases with increasing of the density of the material.

From the results we get from the MCA we observe that the energy of the photons undergo decreasing with increasing of the scattered angle.

The peaks that we get which shows many important details we can get the number of the gamma decay that reach the detector without any absorber to calculate the attenuation of the absorbed materials which shown in the net area of the peak. And also the gross area which represents the number of the photons that reached the detector with the background.

So at the end of the experiment we get good ideas about the nature of the radioactive sources and what is the behavior of its radiation also how to measure the energy of the source and the measurement of the intensity of absorbed photons through the measuring the attenuation of the different materials .

2. References

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